



Community Summer Study  
SN  WMASS  
2022 July 17 - 26 Seattle

# A Tour of International Underground Facilities & Science: Today and Tomorrow

Clarence Virtue  
Interim Executive Director





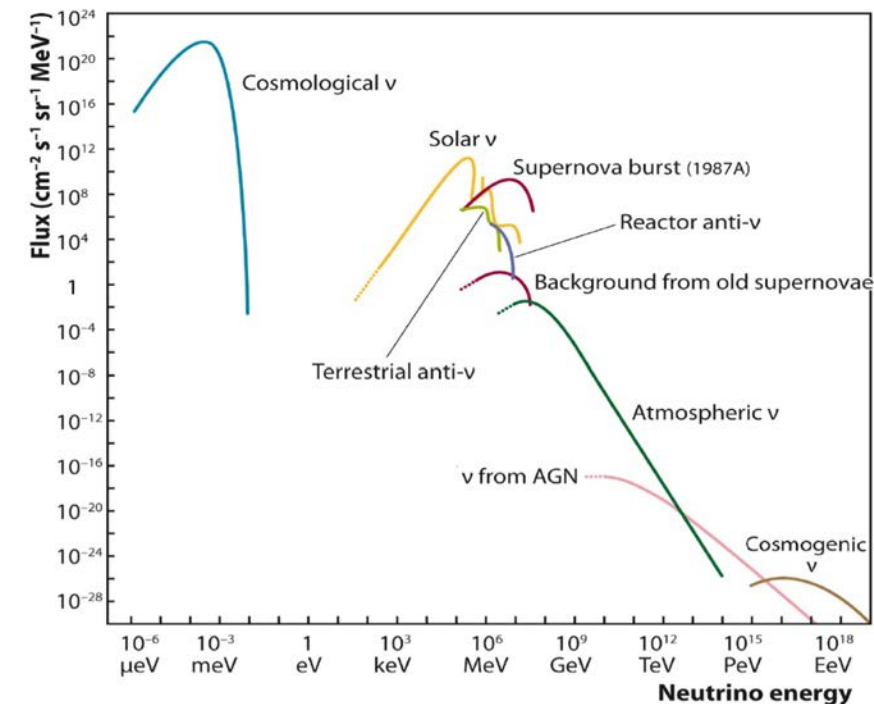
# Why create deep underground facilities?

## To access the science with improved signal to background

- Primarily by reducing cosmic ray muon flux
- Reducing spallation products and avoiding cosmogenic activation of materials
- Making highly sensitive searches for new physics possible, and
- Improving precision on low signal measurements

## Depending on the objective, signals (or backgrounds) have been

- Cosmic rays
- Neutrinos from multiple natural and terrestrial sources
- Dark matter
- Radioactive decay including  $0\nu\beta\beta$  decay
- Ambient neutron and gamma fields, and radon concentrations





# Laboratory attributes

## Physical

- Depth, size (floor space and volume), layout
- Access – horizontal or vertical
- Overburden – flat or not
- Proximity to reactors, coupling to accelerator beams
- Limitations on component size and weight
- Local geology – rock quality, U, Th, K concentrations, water ingress

## Operational

- Scientific Support – laboratory systems QA and development
- Access support, logistics
- Utilities – power, water, internet, LN2, ventilation, chilling
- Integration support - personnel, safety, machine shops
- Project management support, engineering

# Broad Scientific Programme / Diverse Facilities



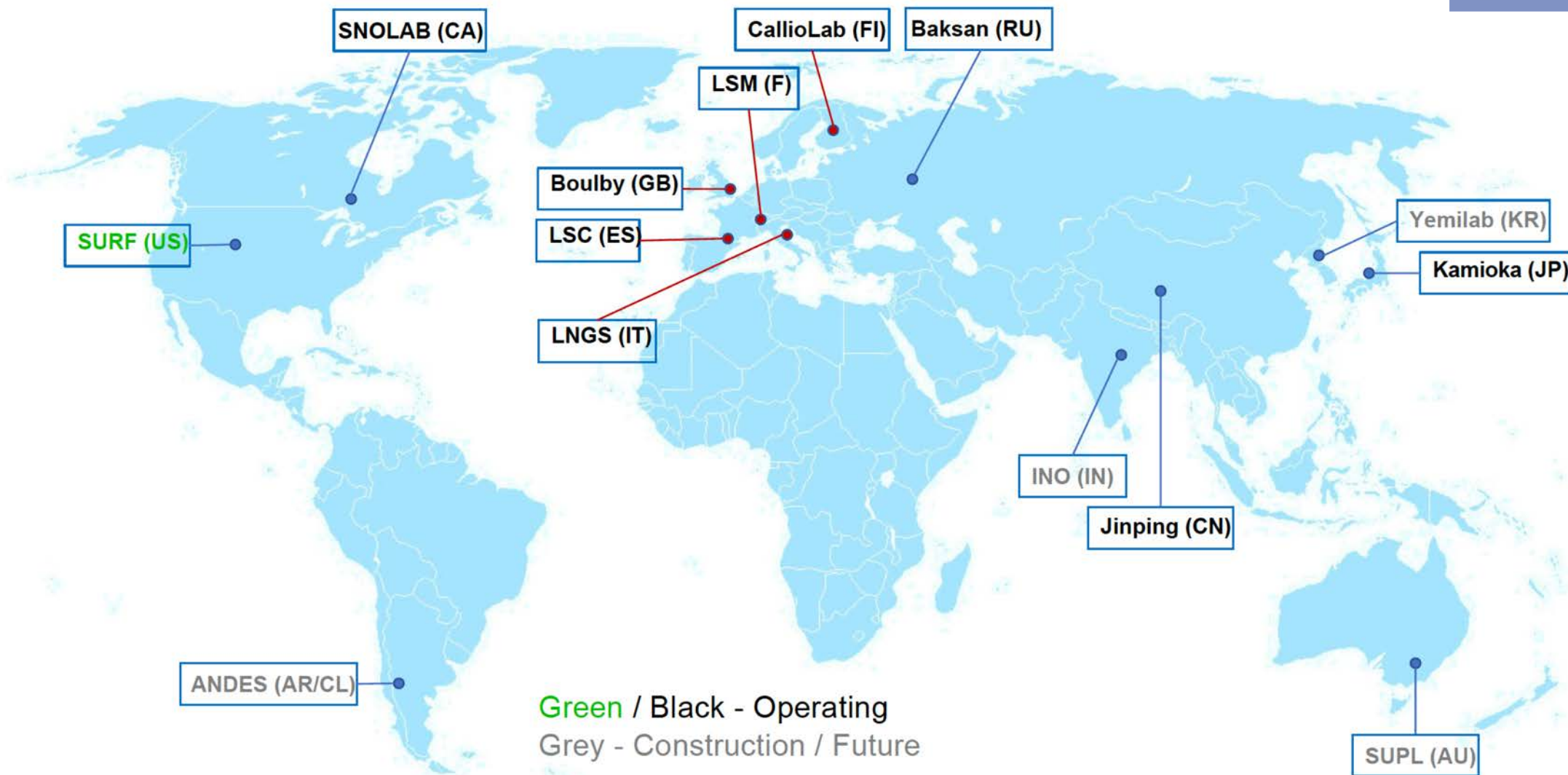
## Diversity in

- Physical and operational attributes
- Challenges associated with specific facilities
  - Material handling logistics
  - Seismicity engineering constraints
  - Rock mechanics
  - Local support
  - Remoteness / travel logistics

## N.B.

- Excluding mega-scale water Cherenkov detectors for neutrino astronomy
- Concentrating on deep, operating, or planned / in construction facilities
- Focus on facilities and their scientific programmes but not generally surveying scientific results
- Drawing on recent (LRT 2022) overviews of facilities presented by Jaret Heise, Sean Paling and Douglas Leonard with input from multiple lab directors

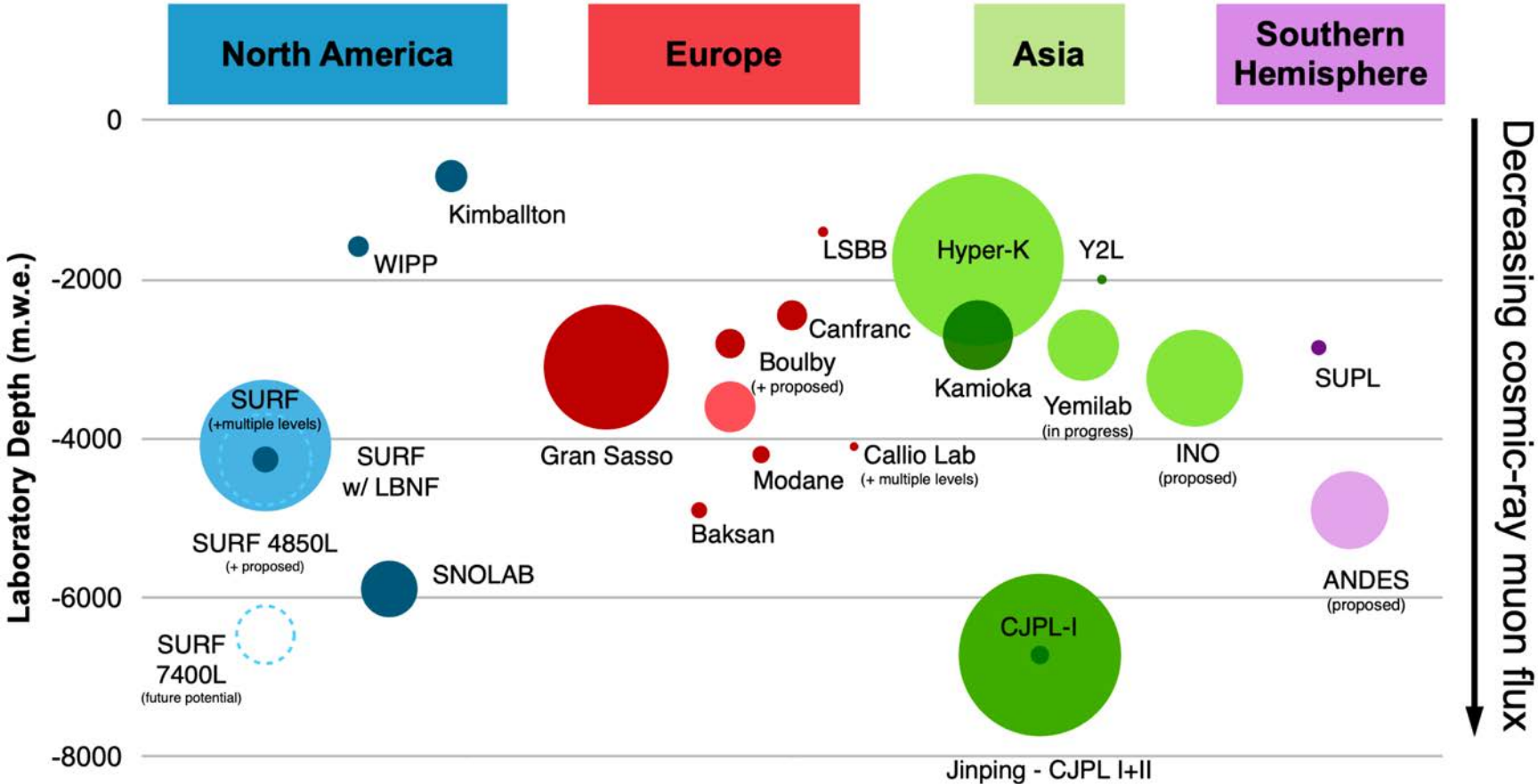
# International Deep Underground Facilities



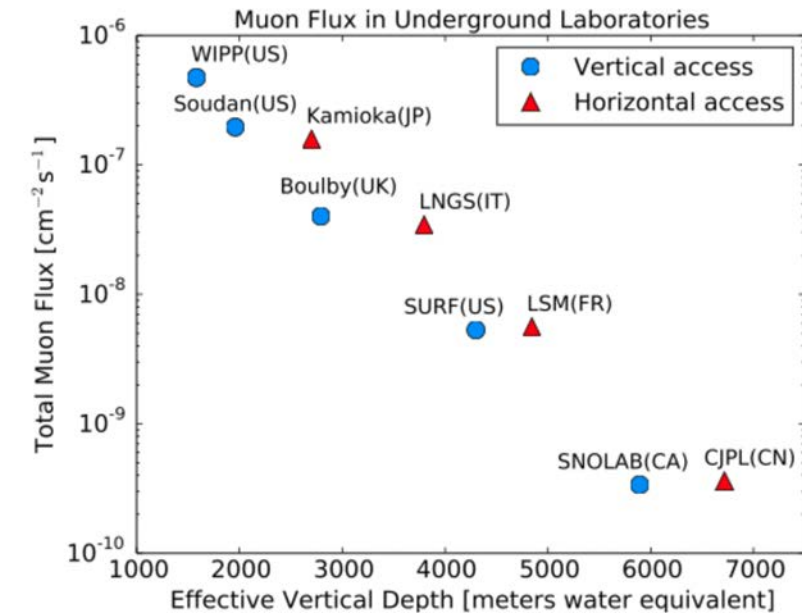




# Some visual attributes



Note: Circles represent volume of science space



adapted from Guo *et al.*, Chinese Physics C45, 025001 (2021).

# Baksan (Russia)

- Celebrated 50 years in 2017
- New results from BEST (Baksan Experiment on Sterile Transitions) V. V. Barinov *et al.*, Phys. Rev. C 105, 065502, June 2022.



View of the Andyrchi mountain near Mount Elbrus in the Northern Caucasus and the Neutrino village, from across the valley.  
Image credit: V Petkov.



Photos from CERN Courier, May 2017



Underground laboratories of the Baksan Neutrino Observatory, at increasing distances from the tunnel entrance (right). Being under a mountain the shielding increases with distance along the tunnel.

Image credit: Y Gavriluk.



The assembled gallium sterile-neutrino experiment (BEST).

Image credit: S Demidov.



# Boulby Underground Laboratory (UK)



## Boulby Facility Details...

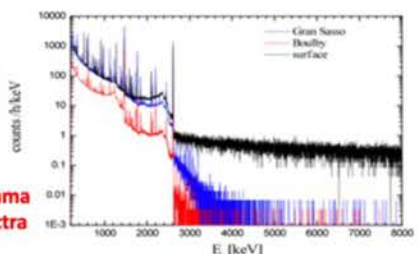
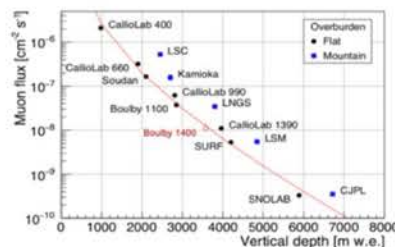


- The UK's deep underground science facility. One of 5 in Europe, <15 in the world.
- Supports work of >10 collaborative projects (astrophysics to climate, geology, environment etc), >40 institutions, >170 scientists & students.
- Facility funded and operated by the Science & Technology Facilities Council (STFC).
- Operations, H&S & science programme managed by 10 (+2) onsite staff and supported by Rutherford Appleton Lab (PPD).
- Mine operators ICL-UK provide wide-ranging operational & high level support.



### How does Boulby Compare?

- Low Radon levels (3 Bq/m<sup>3</sup>)
- Diverse science programme.
- Science and Industry partnership



## Underground Science @ Boulby Mine

- DRIFT/CYGNUS: Directional Dark Matter
- Spherical Proportional Counters (NEWS-G) R&D
- BUGS: Ultra-low background material screening (for LUX-ZEPLIN and Super-K-Gd and more)
- AWE(Ge): Atmospheric gamma spectroscopy
- RESOURCE: Salt cavity energy storage study
- BISAL: Geo-microbiology / Astrobiology studies
- MINAR: Space Exploration Tech. Development
- Misc. Low Background & Geoscience...
- Etc... (More to come).



Astrobiology & planetary exploration

A busy & growing multi-disciplinary science programme: Astrophysics and Low Background science, Earth and Environmental Science, Astrobiology and Planetary Exploration.







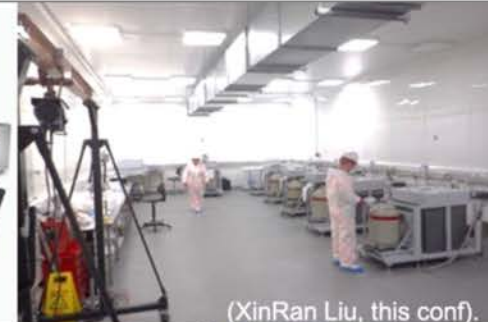
# Boulby Science Now & Future

Particle physics and ultra-low background studies

**BUGS**



XIA alpha particle counter



(XinRan Liu, this conf.)



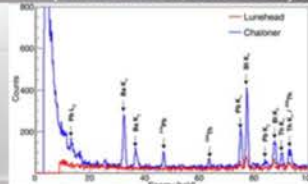
8 ULB Ge detector systems, 2 XIA alpha counters, Rn emanation, ICPMS to come

**BUGS (Boulby UnderGround Screening).** World-class material screening for current and future ULB experiments. Towards PPT sensitivity for G3 DM and Neutrino experiments



Aiming for **ALL** key ULB screening systems under one (1.1km) roof.

LZ PMTs



**Boulby Dark Matter Studies...**

Boulby has hosted **Dark Matter** search studies for over two decades. Including the **NAIAD**, **DRIFT** & **ZEPLIN** experiment programmes.

Boulby now hosts **CYGNUS** directional DM programme, **NEWS-G**/Dark-Sphere R&D and providing ULB material screening for other studies, inc **LUX-ZEPLIN (LZ)**

Galactic rotation curves

**ZEPLIN-II & III:**  
The world's first 2-phase Xenon dark matter detectors (Finished 2011)

World DM particle search limits and future projections

**ZEPLIN-III @ Boulby**

**NEWS-G**  
Spherical Proportional Counter (SPC) studies @ Boulby

k. Nikolopoulos, I. Katsioulas, P. Knights, T. Need, R. Ward  
University of Birmingham  
And wider NEWS-G Collab.

SPC concept: Variable target  
Low  $E_p$ , Low mass sensitivity

Simulation study of neutron interactions in the S30 at Boulby

Neutron Beam 4 MeV

**Direction of R&D at Boulby**

- Instrumentation development alongside NEWS-G at SNOLAB
  - Multi-anode sensor
  - Gas mixtures & filtration
- Working towards scaled-up detector at Boulby, 3m diam. **DarkSPHERE**
- Establishing **Electro-forming Capability** at Boulby for Dark SPHERE and beyond (I. Katsioulas, This conf.)

**SPC Sensitivities**





LOCATED AT THE 1.4 KM (4100 MWE) DEEP PYHÄSALMI MINE, PYHÄJÄRVI, FINLAND

UNIQUE UNDERGROUND RESEARCH NETWORK AND INFRASTRUCTURE - ACCESS, DEPTH, FACILITIES

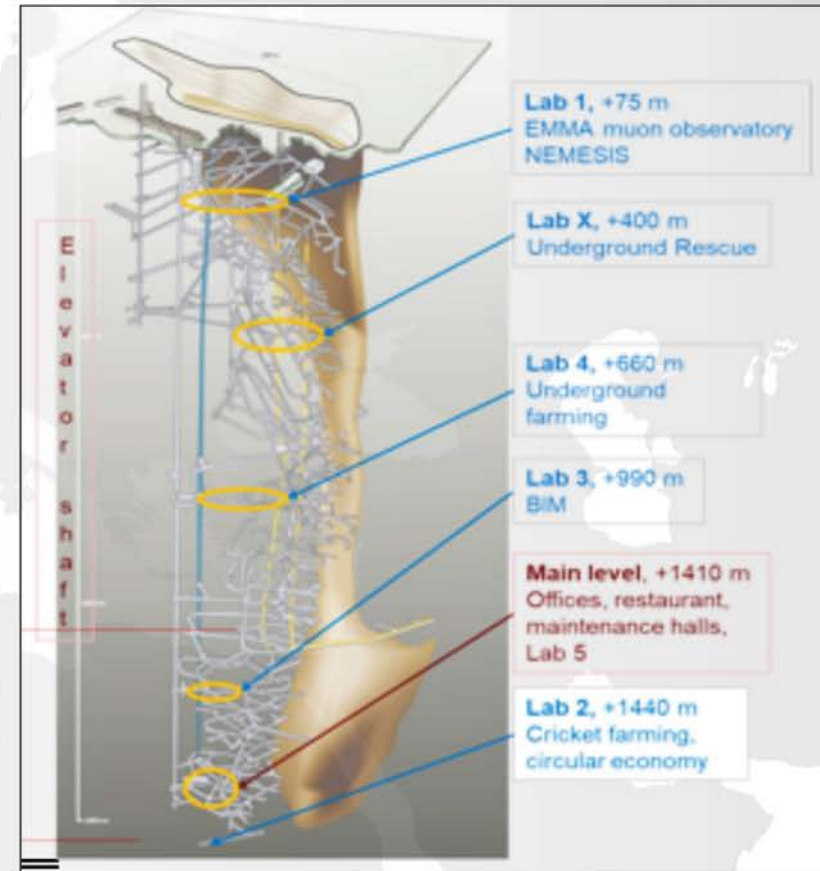
CURRENTLY SIX UNDERGROUND HALLS OR TUNNEL NETWORKS HAVE BEEN TURNED INTO MINE RE-USE FACILITIES: LABS.

MINING ENDS IN JUNE 2022. POST-MINING ACTIVITIES COORDINATED BY CALLIO PYHÄJÄRVI – BUSINESS CONCEPT

MULTI-DISCIPLINARY STEERING GROUP ESTABLISHED 2020



### FACILITIES



Web: [calliolab.com](http://calliolab.com)





### ACTIVITIES

- **EMMA:** Experiment with a MultiMuon Array, cosmic-ray induced bkgds using drift chambers
- **NEMESIS:** New Emma MEasurement with neutronS In cosmic Showers, study neutron bursts in shielding materials (also performed at other European labs)
- **C14:** Measure <sup>14</sup>C isotope in oil-based liquid scintillators (goal of 10e-20 or lower)
- **BSUIN:** Member of the Baltic Sea Underground Innovation Network (13 partners from 8 countries), incl bkgd measurements, develop best practices, etc
- **Goldeneye:** Test site for remote sensing technology (safety and environmental monitoring)
- **Occupational Health:** Intelligent, adaptive lighting studies for UG workers
- Biology & food production, geology & hydrogeology
- UG Rescue & mining training



Coordinator, Jari Joutsenvaara  
(jari.joutsenvaara@oulu.fi)

Project engineer, Julia Puputti  
(julia.puputti@oulu.fi)



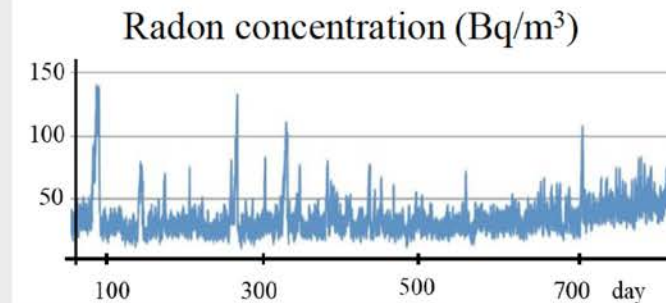
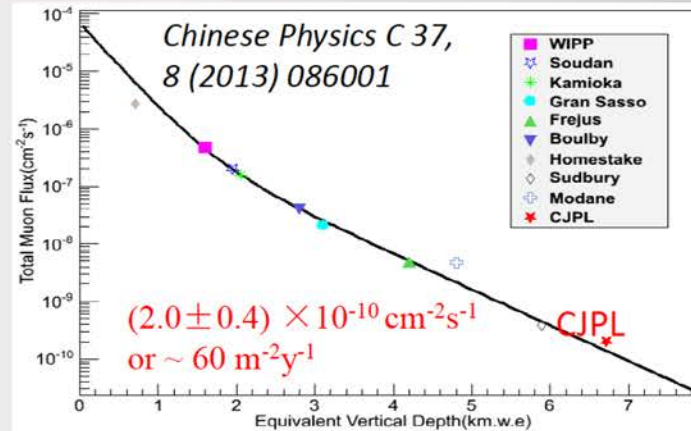
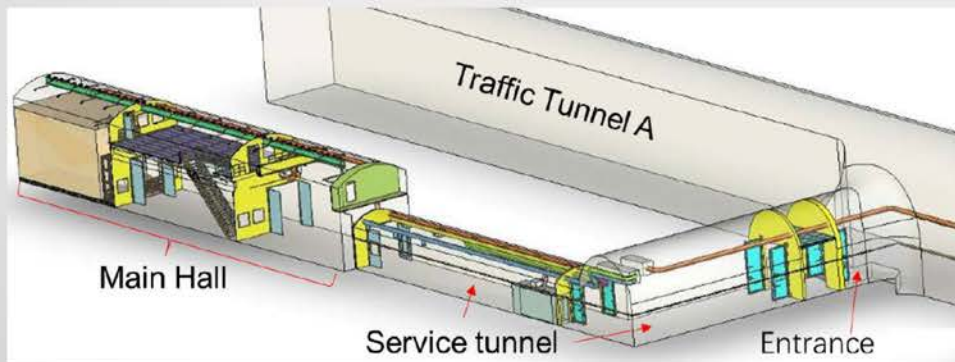
### Future: Globally recognised underground research network and infrastructure





# CJPL Features

- Deepest underground laboratory with a rock overburden of 2400m.
- Open on Dec. 12, 2010, extended from hydro-power facility.
- Total space:  $\sim 4000 \text{ m}^3$ .
- Main Hall:  $6.5\text{m(W)} \times 6.5\text{m(H)} \times 42\text{m(L)}$ .
- Low Muon flux and environmental background.



Rock sample(Marble) measurement by Germanium

(Unit : Bq/kg)	K-40	Ra-226 (609keV)	Th-232 (911keV)
Rock Sample	< 1.1	$1.8 \pm 0.2$	< 0.27
Ground Level(Beijing)	$\sim 600$	$\sim 25$	$\sim 50$



- [illegible]



## Ventilation tubes

Science, Nov. 30, 2014



# Science at CJPL

Hao Ma et al 2021 J. Phys.: Conf. Ser. 2156 012170

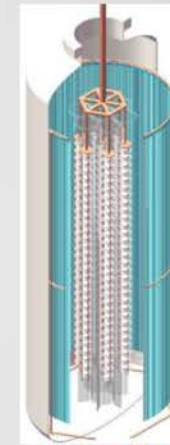


## CJPL-I

- CDEX-1 p-type **Ge WIMP search in PE room**. Excludes DAMA/LIBRA region.
- CDEX-10 Ge **in LN2**. WIMP and dark photon search
- PANDAX-II 580kg Xe TPC.

## CJPL-II

- CDEX-50 (DM-search), WIMP-nucleon SI coupling cross section **goal:**  $10^{-44} \text{ cm}^2$  at WIMP mass  $< 10 \text{ GeV}/c^2$ .
- CDEX-300v  $0\nu\beta\beta$  with p-type point contact (PPC)  $^{76}\text{Ge}$  in **purified LAr** in LN2 tank, half-life goal  $> 10^{27}$  years.
- PandaX-4T: 3.7-tonne of liquid Xenon, in B2 hall (water tank), SI DM CS limit **results:**  $3.8 \times 10^{-47} \text{ cm}^2$  at  $30 \text{ GeV}/c^2$ . Yue Meng et al., Phys. Rev. Lett. **127**, 261802
- JUNA in A1 hall, **accelerator-based nuclear astrophysics**, accelerator installed in 2020, with some early results. Liu, W.P., Li, Z.H., He, J.J. et al. Few-Body Syst **63**, 43 (2022)
- Full commissioning of CJPL-II  $\rightarrow$  March 2023.



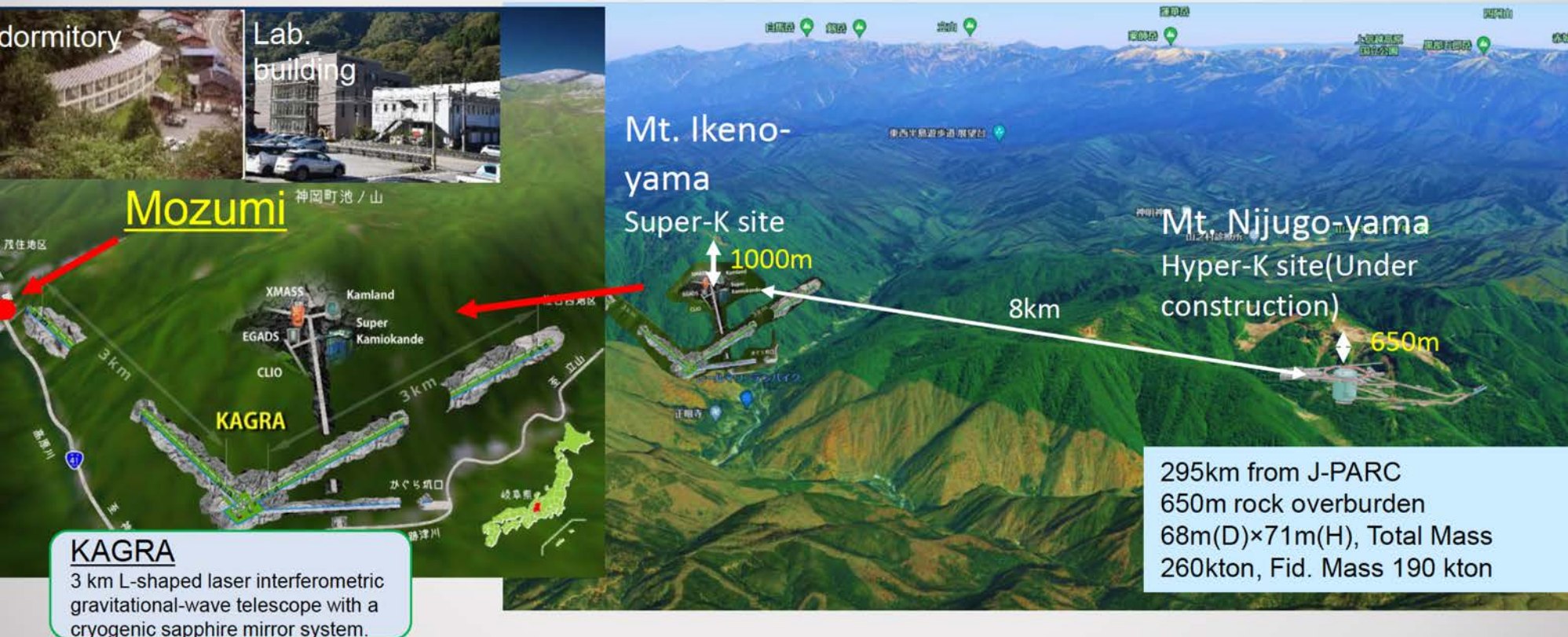
Qian Yue's  
CDEX-300v  
talk, TAUP  
2021.



# Kamioka underground facilities (Mt. Nijugo-yama)

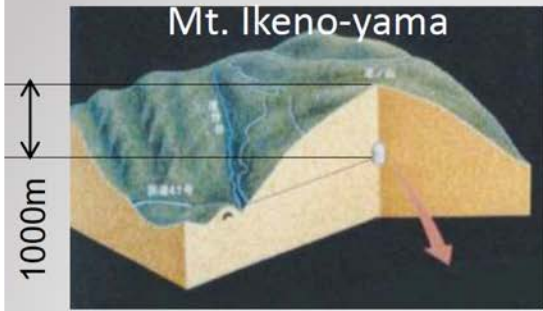
Following SK slides collected by Hiroyuki Sekiya  
(slightly modified)

Hyper-Kamiokande is under construction in Mt. Nijugo-yama 8km south from Super-K



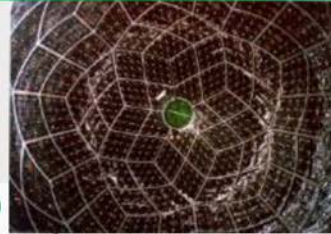


# Kamioka underground facilities (Mt. Ikeno-yama)



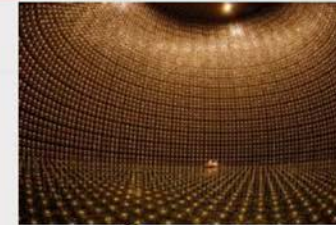
## KamLAND (Tohoku Univ.)

1000ton liquid scintillator detector  
Reactor, geo, low-energy astrophysical  
neutrinos.  $^{136}\text{Xe}$  double beta decay



## Super-Kamiokande

50,000m<sup>3</sup> Gd-water Cherenkov detector.  
Atmospheric, solar, supernova neutrinos,  
DSNB, proton decay, indirect dark matter  
search. Far detector for T2K.



## CANDLES

CaF<sub>2</sub> scintillation detectors  
for  $^{48}\text{Ca}$  double beta decay



## XMASS

Direct dark matter search  
experiment using 1 ton of  
single-phase liquid xenon.  
Data taking was completed.



## NEWAGE

Direction-sensitive direct dark  
matter search experiment  
with a low pressure TPC and  
MPGD readout.



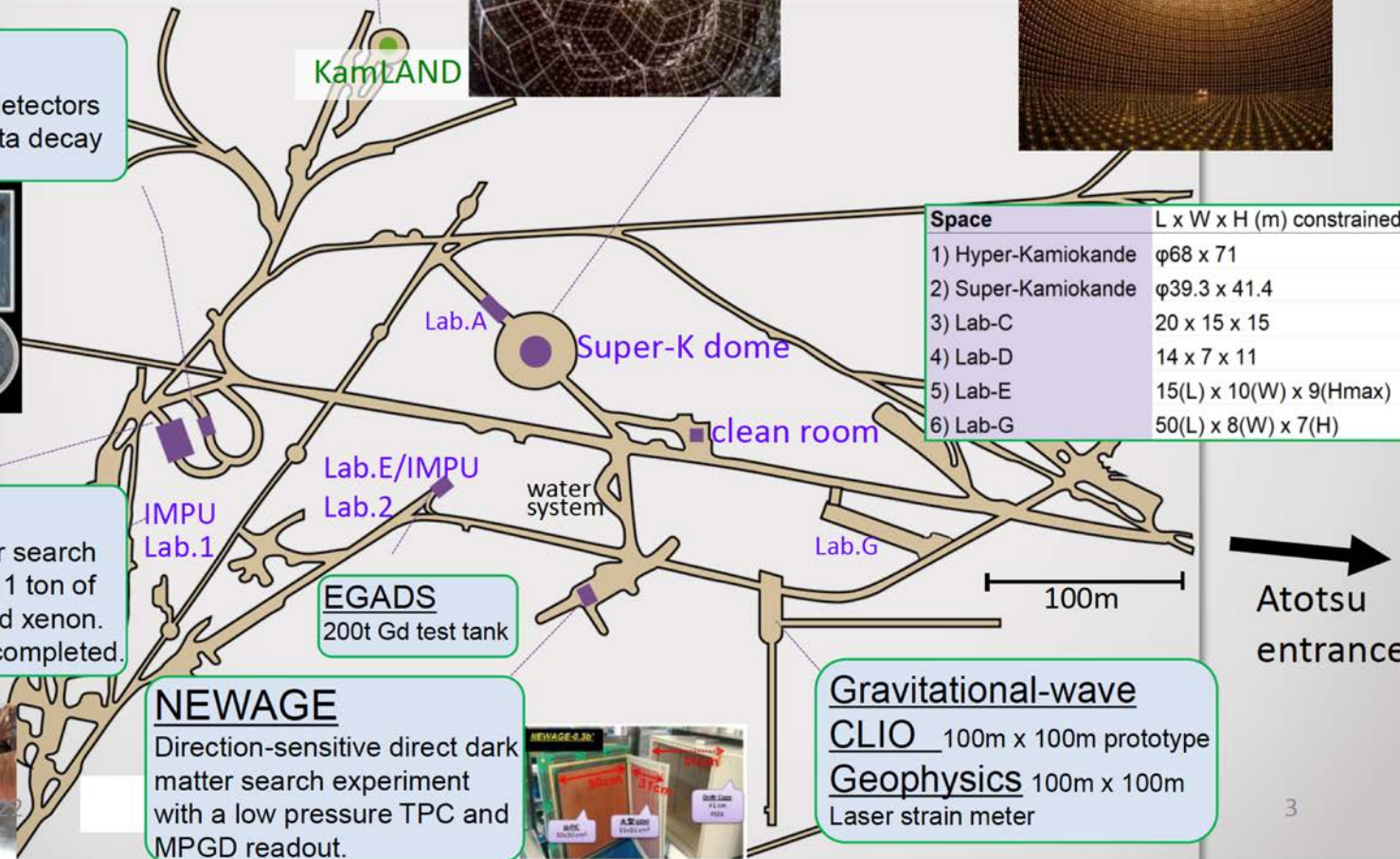
## EGADS

200t Gd test tank

## Gravitational-wave

CLIO 100m x 100m prototype

Geophysics 100m x 100m  
Laser strain meter



Atotsu  
entrance



# Hyper-Kamiokande

arXiv:1805.04163

260,000 tonnes H<sub>2</sub>O

40,000 PMTs

68m D x 71m H

The center of HK dorm



50cm PMTs being produced  
in Hamamatsu  
and checked in Kamioka

Credit: Hamamatsu Photonics K.K



Access tunnel



- Completion of 2km access tunnel excavation in Feb.2022
- Detector cavern excavation scheduled in 2022-2024
- Start operation in 2027

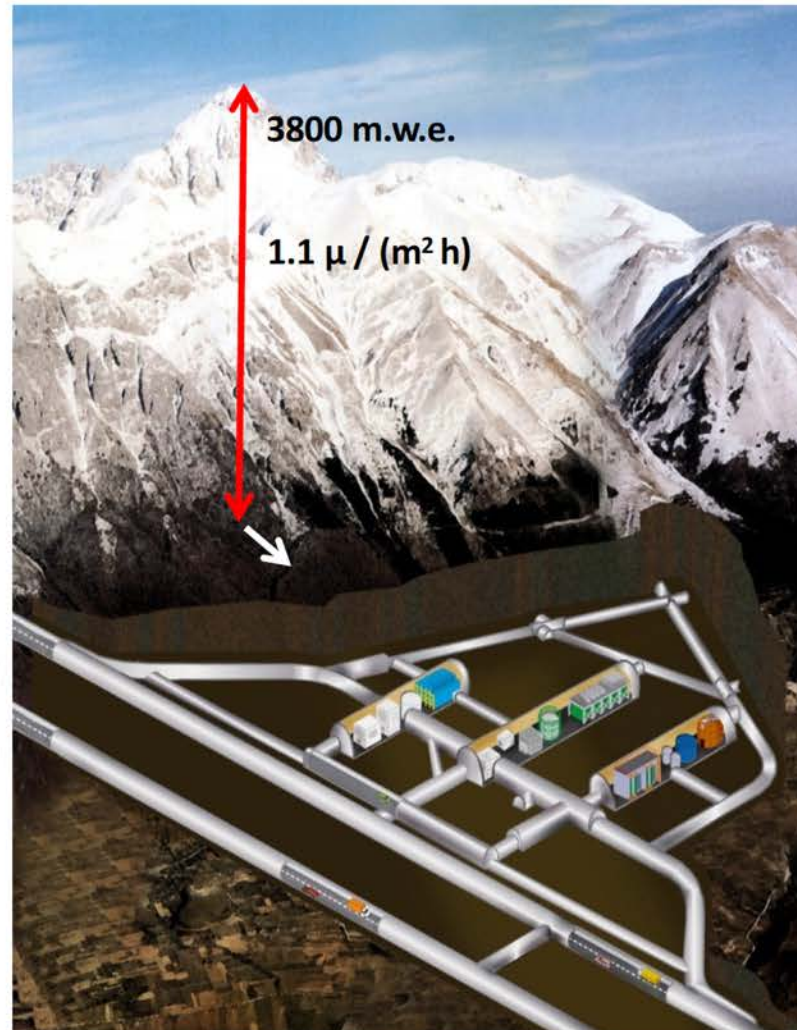
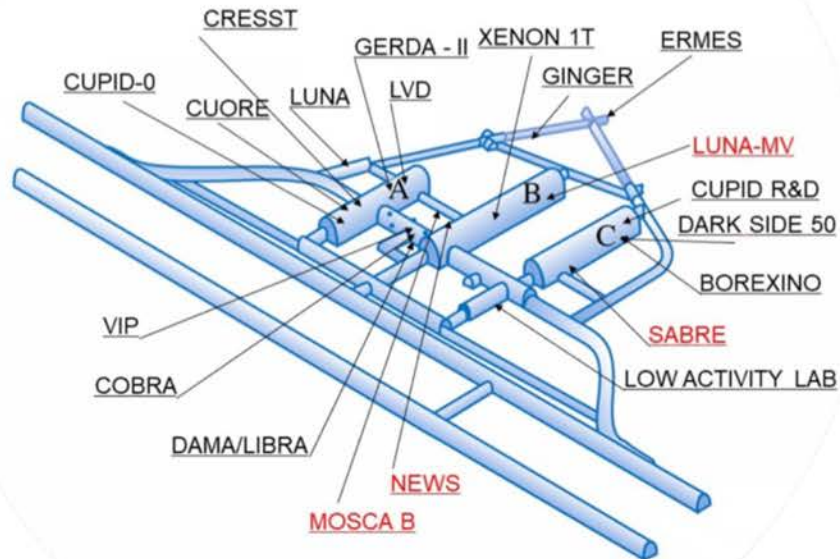
アクセス坑道掘削完了



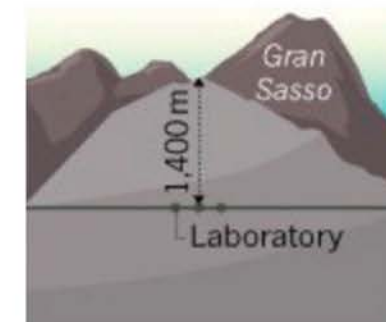
# LNGS / Gran Sasso Deep Underground Lab



- Shielded by 1400 m (3800 m.w.e.) of rock (Gran Sasso Mountains)
- Total Muon flux  $3 \times 10^{-8} \text{ cm}^{-2} \text{ s}^{-1}$
- Radon  $\sim 100 \text{ Bq/m}^3$  with 5-8 air changes/day
- 3 main experimental halls: 100 m long, 20 m width and 18 m height (Vol =  $180,000 \text{ m}^3$ )
- 22 experiments data taking or under construction
- Laboratory for very low radioactivity measurements



Area: **17.800 m<sup>2</sup>**  
Volume: **180.000 m<sup>3</sup>**



E. Previtali





# Gran Sasso Science

## Neutrino Astrophysics



## Nuclear Astrophysics

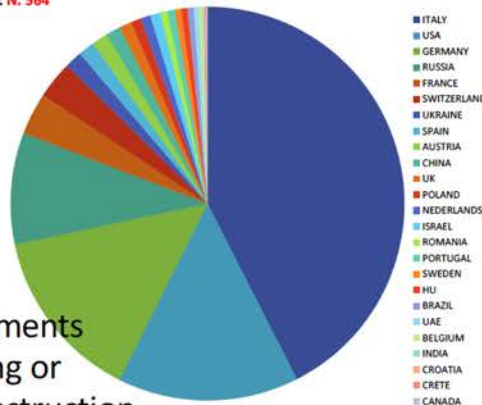
## Dark Matter Search



TAUP2021, 26 August – 3 September 2021

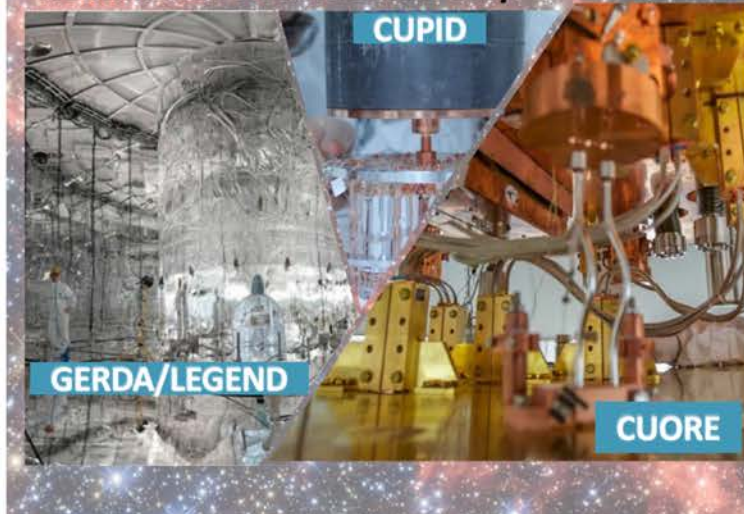


TOTAL USERS: N. 981  
ITALIAN USERS: N. 417  
FOREIGN USERS: N. 564



22 experiments  
data-taking or  
under construction

## Neutrinoless Double Beta Decay



..... but also

- **Test on quantum mechanics**
  - Study on Planck invariance
  - Electron decay
- **Radiobiology**
  - Biological effects of low radioactive environment
- **Geophysics**
  - Earthquake monitoring and study
  - Analysis of water resources
- **Ultra Trace elemental analysis**
  - Low radioactivity tests and measurements
  - Cultural Heritage analysis
  - Advanced additive manufacturing

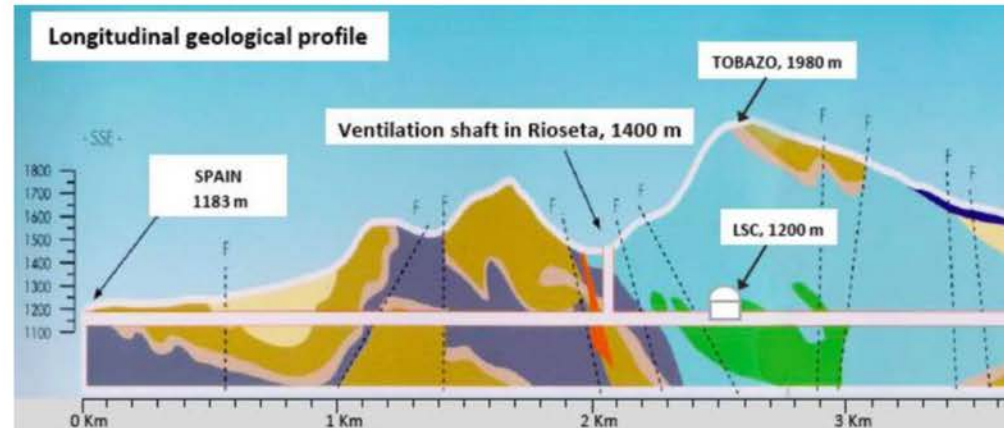
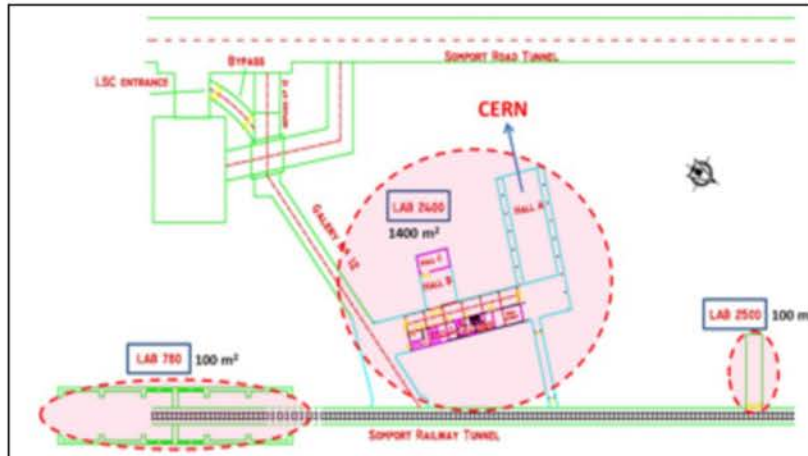
E. Previtali



# Canfranc - LSC



- Depth: 2450 mwe
- Volume: 10,000 m<sup>3</sup>
- Radon: 50-80 Bq/m<sup>3</sup>
- Access: Horizontal
- Rail tunnel between France & Spain



1986 - First experiments in train tunnel  
 2003-2006 - new lab built 1600m<sup>2</sup>  
 2007-2010 - refurbishment works  
 Since 2010 - re-start experimental activities  
 Previous Directors: A. Bettini, A. Ianni

Inlet air flux: 20000 m<sup>3</sup>/h  
 Radon: 50-80 Bq/m<sup>3</sup>  
 Radon-free: 1mBq/m<sup>3</sup>, 220 m<sup>3</sup>/h  
 Muons:  $(5.3 \pm 0.2) \cdot 10^{-3} \text{ m}^{-2}\text{s}^{-1}$   
 Neutrons:  $3.5 \cdot 10^{-6} \text{ cm}^{-2}\text{s}^{-1}$







## Experiments

### Neutrino physics

- **NEXT** –  $^{136}\text{Xe}$  high-pressure gas TPC (data and construction)
- **CROSS** – Cryogenic Observatory with Surface Sensitivity for CUPID
- **SK-Gd & Hyper-K** – Screening and R&D (e.g., PMT covers)

### Dark matter searches

- **ANAIS** – 112 kg NaI crystals (3-yrs data) to verify DAMA-LIBRA
- **DaRT** – Argon activation detector for DarkSide (GADMC)
- **TREX** – Nobel gas (Ne,Ar) high-pressure TPC

## Lab Services

### HP Ge detectors

### Electroformed Cu facilities

### Rn reduction (220 m<sup>3</sup>/h)

### Rn monitoring (1 mBq/m<sup>3</sup>)

### Rn-emanation detector






**NEW LINE: BIOLOGY UNDERGROUND**


Life in Heavy Water and its Energy Source [CBMSO] - Microorganisms in D<sub>2</sub>O  
 Darwinian evolution (De Luria-Delbruck) [I2SysBio] - E. Coli  
 DNA Damage repair [UPF] - E. coli  
 Multicellular Structure Formation [IBE] - S. Arctica, C. Owczarzak  
 Interaction between host and pathogens [I2SysBio] - C. Elegans, Q. Nodavirus

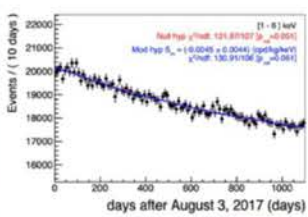
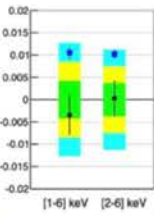


New biolab underground. Explore suppression of DNA repair mechanisms. Expressions of Interest approved.

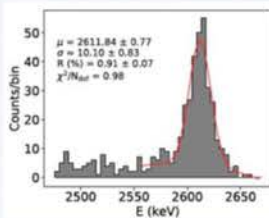
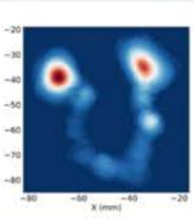


**LSC MAIN SCIENCE RESULTS IN 2021**



ANAIS: 3 years data published  
5 years data in 2022 (on DAMA/LIBRA claim)

NEXT-NEW phase completed  
Great Energy res. & e-reconstruction!

**Future aims:** NEXT: Ton-scale. Hyper-K construction, cryogenic technologies and misc. low background R&D.

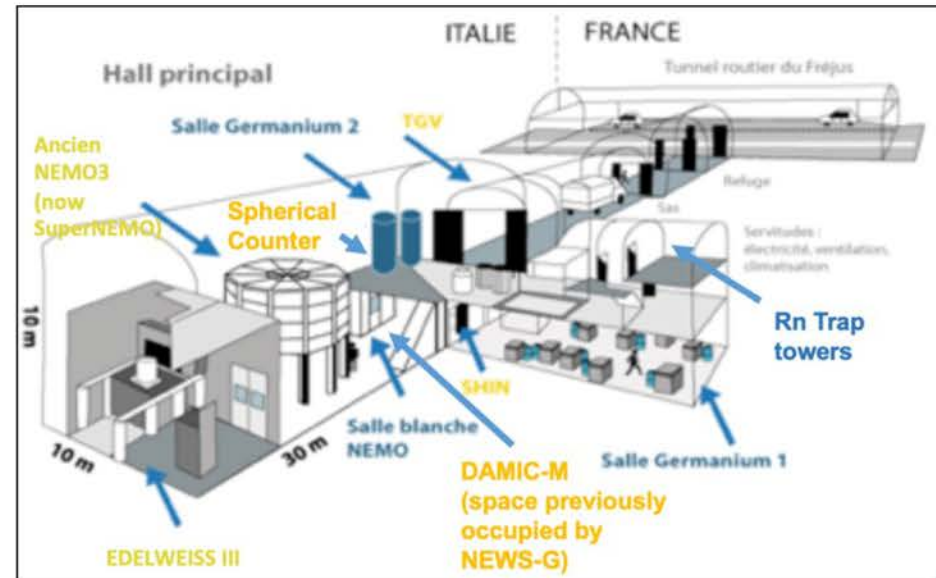


# LSM Status & Plans



## Laboratoire Souterrain de Modane (LSM)

- Depth: 4800 mwe  
(Deepest UG Lab in EU)
- Volume: 3500 m<sup>3</sup>
- Radon: ~15 Bq/m<sup>3</sup>
- Access: Horizontal
- Staff: ~ 13
- Projects: 7-9



June 2022

LSM current status and plans







LPSC  
PLATEFORME NATIONALE LSM



LSM

# LSM current status and plans

- **Science program adapted to LSM size:**
  - Low-mass Dark Matter Experiments
  - $0\nu\beta\beta$  demonstrators & technologies
  - HPGe array for low-radioactivity

## Low-mass Dark Matter

### Recent physics results:

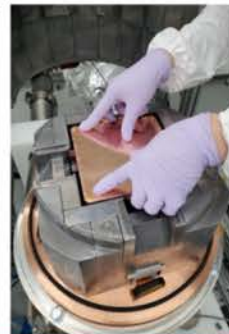
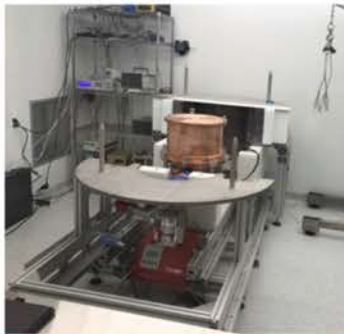
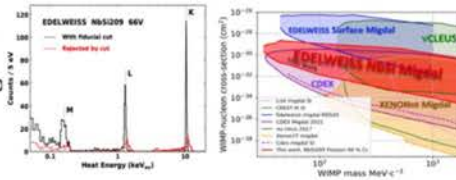
- **EDELWEISS** [arXiv:2203.03993] Migdal limits for  $<35$  MeV WIMPs with 200g Cryo with new NbSi TES phonon sensor

### In preparation / coming results:

- **CRYOSEL:** Cryogenic Ge with single- $e^-$  tag using  $\mu$ -wire NbSi TES sensor: 40 g detector in BINGO cryostat @ LSM (2023)

- **DAMIC-M:** Search for low-mass Dark Matter with 1kg skipper CCDs

- Start of physics run with 2 CCDs (1 kg.d goal)



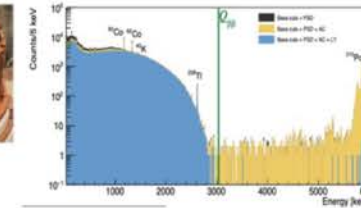
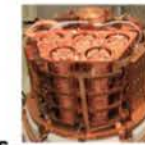
June 2022 LSM current status and plans

2

## $\beta\beta 0\nu$ demonstrators & technologies

### Recent physics results:

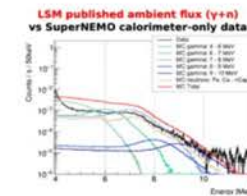
- **CUPID-Mo** 20 x 0.2 kg scintillating Bolometers. Mo- $^{100}$  test, CUPID demo
- [arXiv:2202.08716] **New leading limits on  $^{100}\text{Mo}$   $0\nu\beta\beta$  & beta decays**



### In preparation / coming results:

- **BINGO:** Development of next generation cryogenic  $\beta\beta 0\nu$  technologies with reduced support mass, Neganov-Luke light detectors and active shield

- **SuperNEMO installation and commissioning**



Tracko-Calorimeter detection of  $bb0n$  decays with identification of the two electron tracks



June 2022

LSM current status and plans

3



# SNOLAB (Canada)



## Partner Universities



## Partners



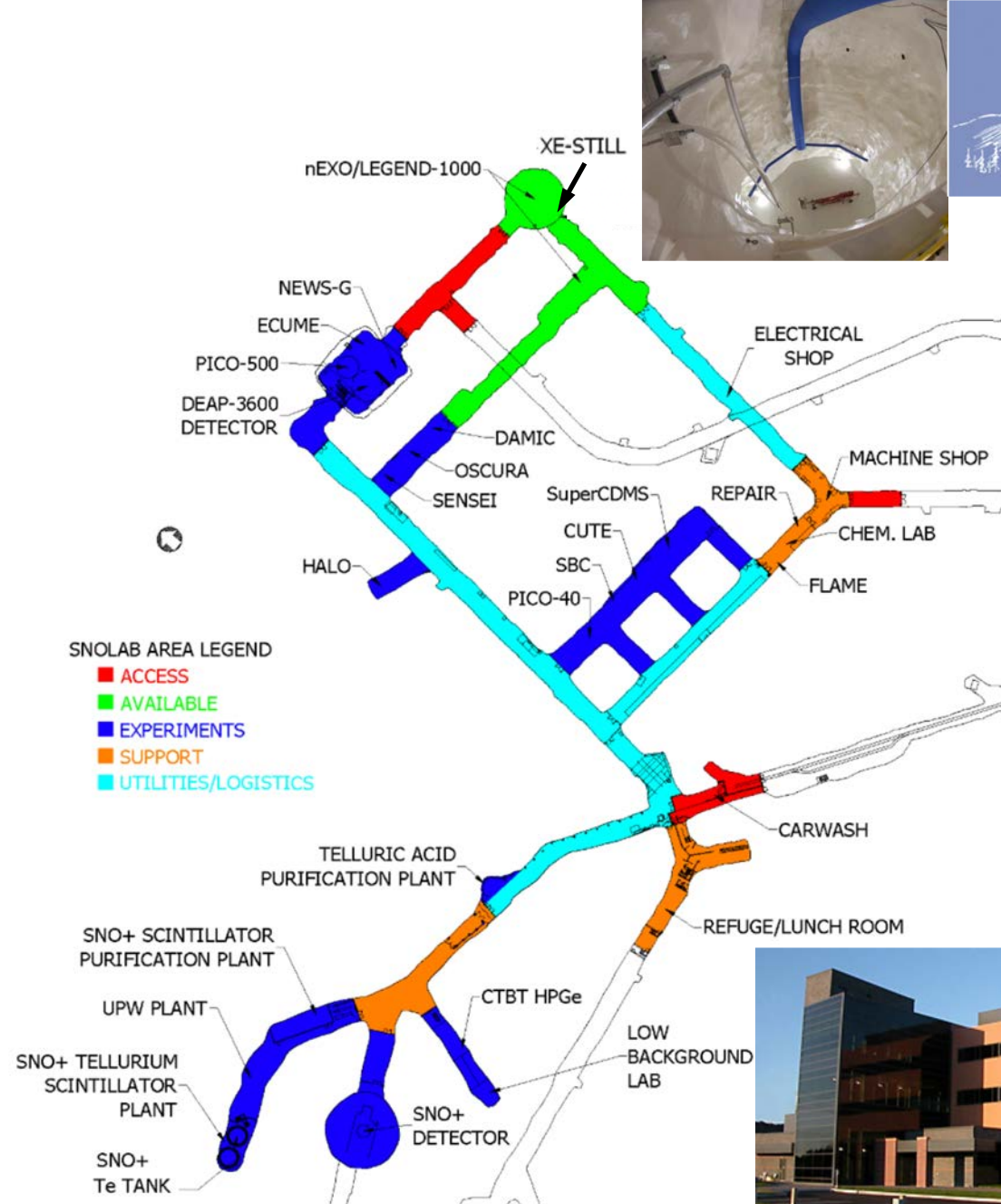


# 6800' lab layout

(6000 m.w.e. /  $0.3 \mu \text{m}^{-2} \text{day}^{-1}$ )

- Cryopit is allocated to the tonne-scale  $0\nu\beta\beta$  program
- Otherwise all available space is occupied and actively managed under SNOLAB's project lifecycle program
- A conceptual design for a lab expansion exists...

Map of the underground facility showing locations of experiments and various ancillary areas.



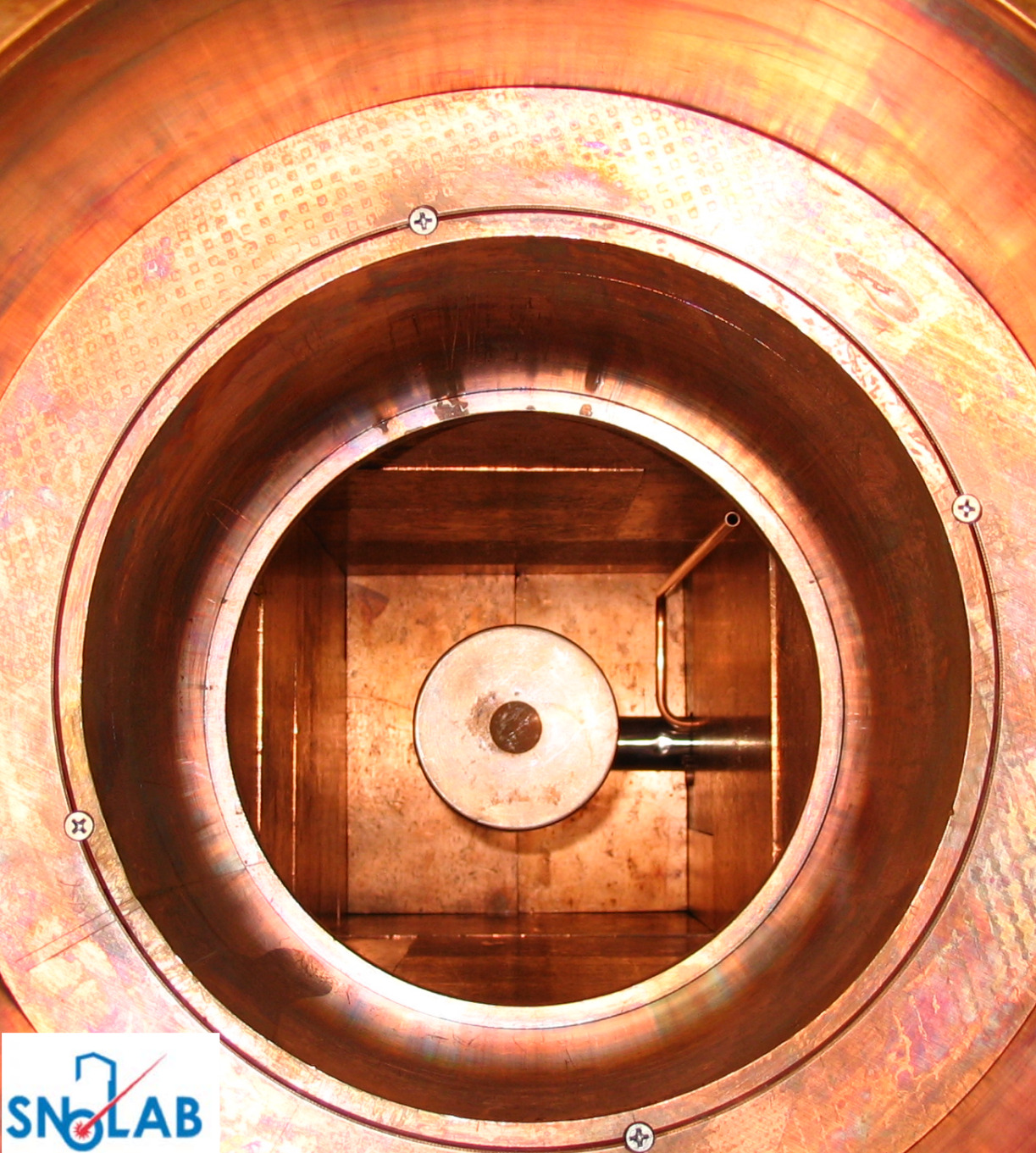


Experiment	Research Focus					Status	
	Dark Matter	Neutrino 0vBB	Neutrino Other	Supernova	Other	Space allocated	Phase
Ar2D2	✓				Low-rad argon	LBL	Letter of Intent
ARGUS-I	✓	✓			Ar storage	4000L	Letter of Intent
COUPP-4	✓					Ladder Labs	Completed
CTBT-HPGe					Low background	LBL	In construction
CUTE	✓				Test facility	Ladder Labs	Operational
DAMIC	✓					J-Drift	Operational
DEAP-1	✓					J-Drift	Completed
DEAP-3600	✓					Cube Hall	Completed
DEAP-3600-II	✓					Cube Hall	In construction
ECUME					Cu electroform	Cube Hall	In design
FLAME					Genomics	Bio/chem lab	Operational
HALO				✓		Exp. Stub	Operational
LEGEND-1000		✓				Cryopit	In design
LNG-CTF					Cryogenics	Surface Facility	In design
MiniCLEAN	✓					Cube Hall	Completed
MODCC					Mining data	Surface Facility	Completed
nEXO		✓				Cryopit	In design
NEWS-DM	✓					Cube Hall	Discontinued
NEWS-G	✓					Cube Hall	Operational
OSCURA	✓					J-Drift	Letter of Intent
PICASSO-III	✓					Ladder Labs	Completed
PICO-2L	✓					J-Drift	Completed
PICO-60	✓					Ladder Labs	Completed
PICO-40L	✓					Ladder Labs	Operational
PICO-500	✓					Cube Hall	In preparation
PUPS					Seismicity	External drift	Completed
SBC	✓					Ladder Labs	In preparation
SENSEI	✓					J-Drift	Operational
SNO+ (H2O)			✓	✓		SNO Cavity	Completed
SNO+ (LAB)			✓	✓		SNO Cavity	Operational
SNO+(Te)		✓	✓	✓		SNO Cavity	In construction
SuperCDMS	✓					Ladder Labs	In construction
REPAIR					Genomics	Bio/chem lab	Operational
Xe-Still					Cryogenics	Cryopit	Operational

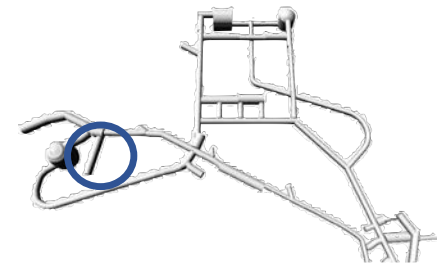
# SNOLAB Experimental Programme

- 10 operational
- 4 in construction
- 9 in pipeline in various stages
  - letter of intent
  - in design
  - in preparation





# SNOLAB is increasing low background screening capabilities



## HPGe Detectors:

PGT Coaxial Detector , Canberra Coaxial Detector (**Lively**),  
Canberra **Well** Detector, Eurisys Mesures Coaxial Detector  
(**Vue Des Alpes**), Canberra Coaxial Detector (**Gopher**),  
Canberra Dual HPGe (**CTBT**)

## Alpha Counting:

XIA UltraLo-1800

## Radon Emanation Measurements:

Electrostatic Counter (**ESC**)

Radon Emanation Studies using Bronze and Xeolite/charcoal traps

Radon Board on Water Svstem





# New Underground LN2 Plant

The LN2 Plant is operational since May 2022, creating high purity LN2 (99.999%) at 3,000 L/week.

It is being tied in to supply SNO+/UPW Plant. It is currently used for cooling down the HPGe detectors and will soon provide it GN2 through the LBL gas distribution system. It is currently supplying the CUTE facility, and soon all users at SNOLAB will use this LN2 system.





# SUPL / Yemilab



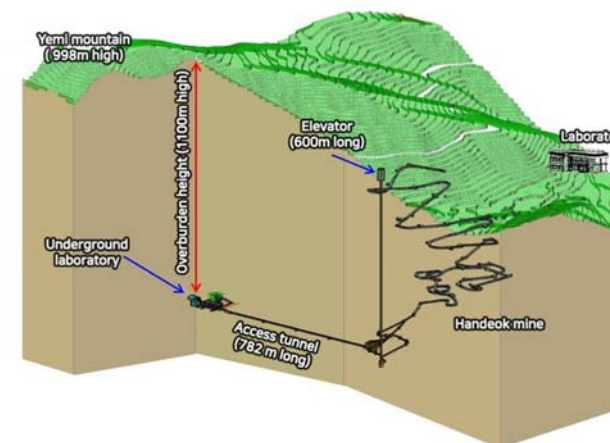
## SUPL (Stawell Underground Physics Lab – Australia)

- Being built at depth of 1000 m
- First UG lab in southern hemisphere
- To participate in DM searches



## Yemilab (Korea)

- New, being constructed at 1100 m depth
- Deeper than Kamioka but smaller



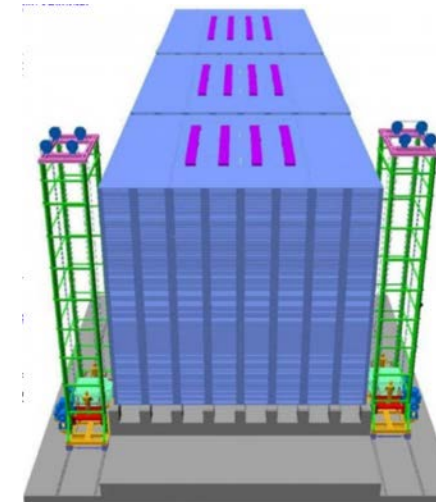
# INO / ANDES

## INO (India-based Neutrino Observatory)

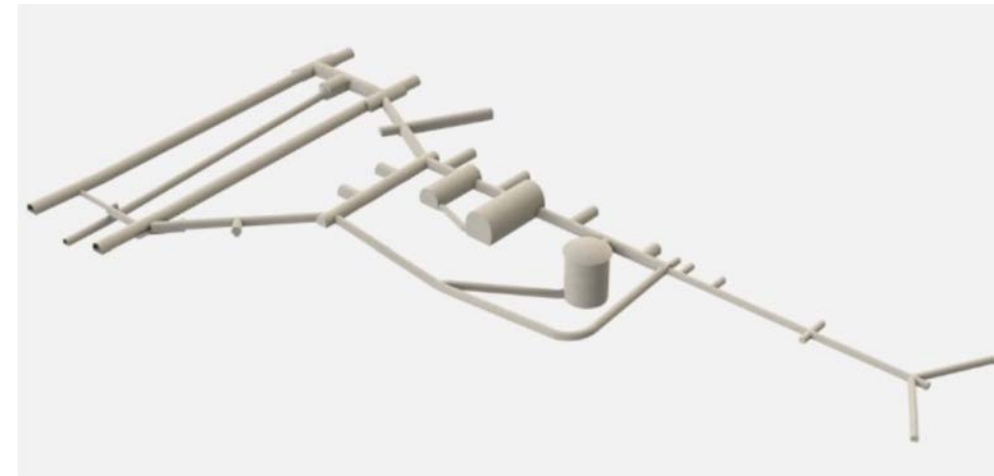
- Planned for 1200 m cave
- Construction delayed
- National with international involvement

## ANDES (Agua Negra Deep Experiment Site – Argentina / Chile)

- Deep: 1750 m rock overburden
- Large: 4000 m<sup>2</sup>, 70000 m<sup>3</sup>
- Planned as an international laboratory run by a consortium
- Agua Negra tunnel situation unclear



Schematic of a detector at the observatory. Photo: INO website







# Future paths

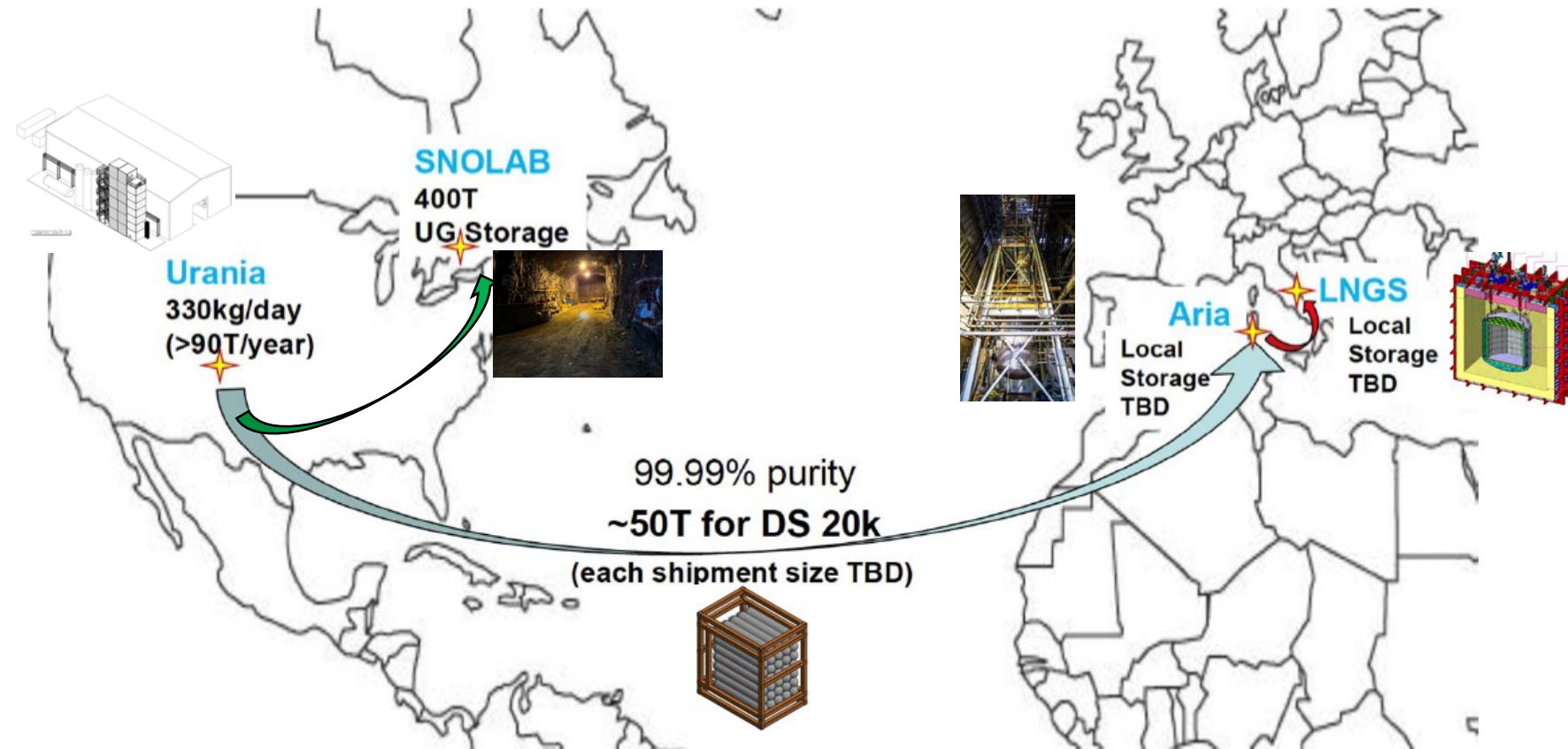
## G3 Dark Matter

- Liquid Argon-based (GADMC – Global Argon Dark Matter Consortium)
  - ARGO LAr 300 tonne to follow Darkside programme
  - SNOLAB is target location
- Liquid Xenon-based (XLZD – XENON LUX-ZEPLIN Dark matter consortium)
  - DARWIN LXe 40 tonne-scale
  - Multi-purpose detector

## G2 $0\nu\beta\beta$ Decay

- Tonne-scale neutrinoless double-beta decay with enriched isotopes
  - nEXO 5T  $^{136}\text{Xe}$
  - LEGEND-1000 1T  $^{76}\text{Ge}$
  - Both have SNOLAB as preferred location; LEGEND-1000 has LNGS as alternate site

# Storage of Low Radioactivity Argon



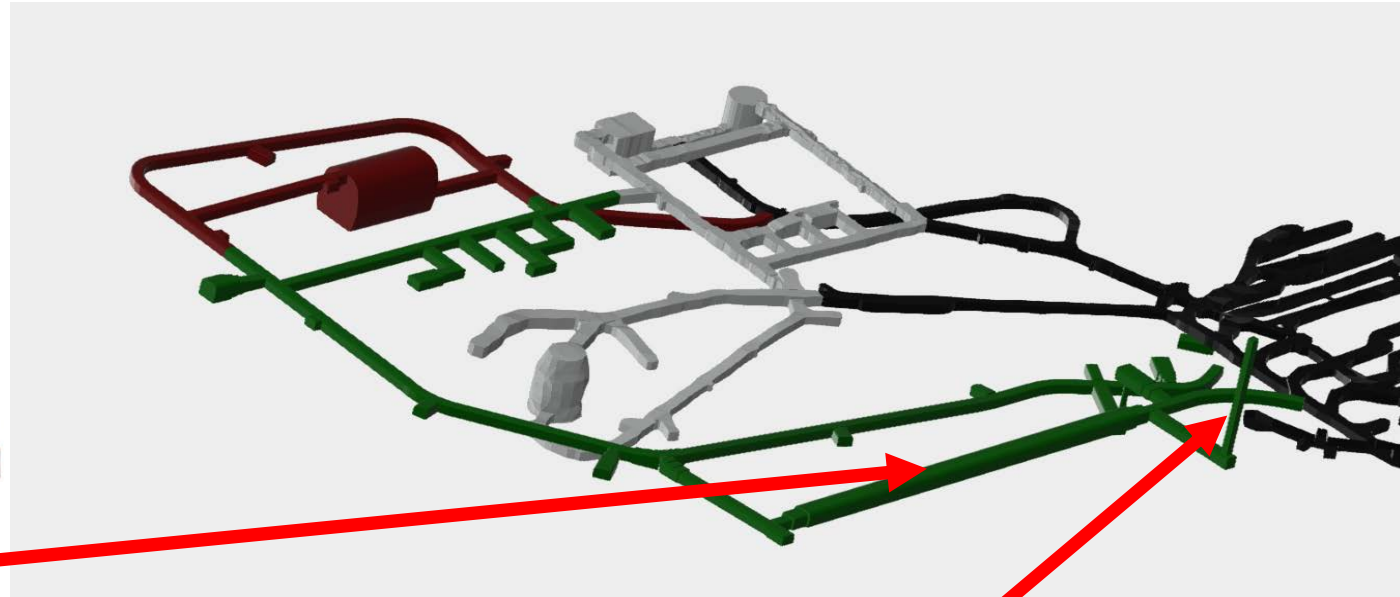
- The GADMC and DarkSide collaborations have built the Urania separation plant to produce argon with very low in  $^{39}\text{Ar}$  activity from an underground  $\text{CO}_2$  production source.
- With the initial production planned to be shipped to Italy for DS-20k, the plant can then continue production for future requirements.
- There is a unique global opportunity to harvest and store this radio-pure argon for future experiments such as LEGEND, COHERENT, Argo, and DUNE.



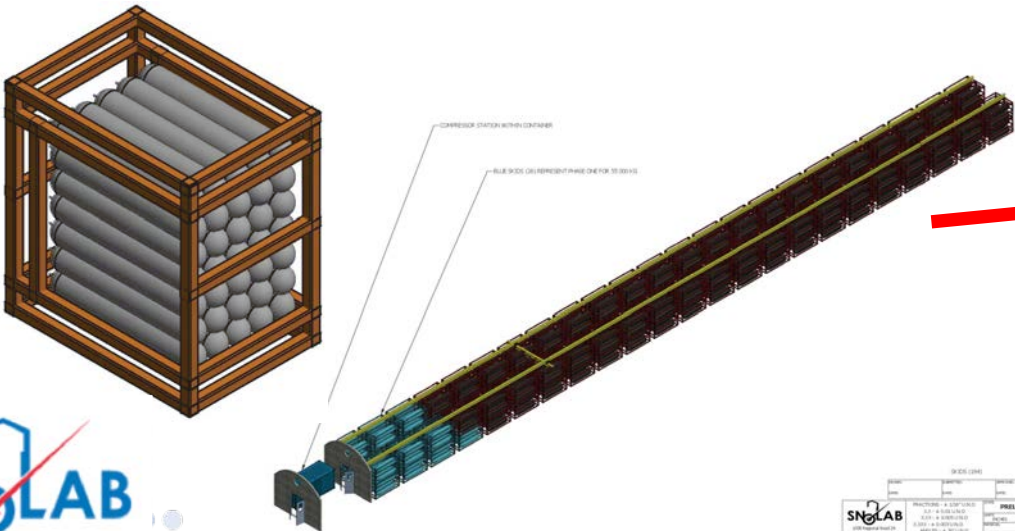
# SNOLAB Expansion Conceptual Design



- SNOLAB has completed a conceptual design for the underground lab expansion to create new experiment spaces and underground facilities. SNOLAB is now seeking a funding opportunity for this expansion.
- Part of the expansion design includes a gas storage terminal for up to 400 tonnes noble gas, e.g. argon.
- The design also includes a raise for a noble gas distillation column.



Distillation column raise

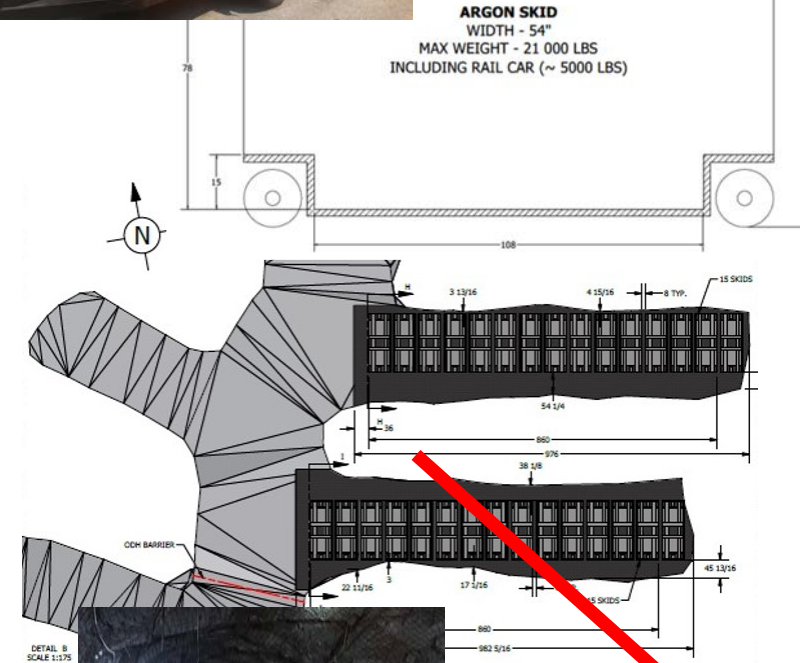


# ARGUS

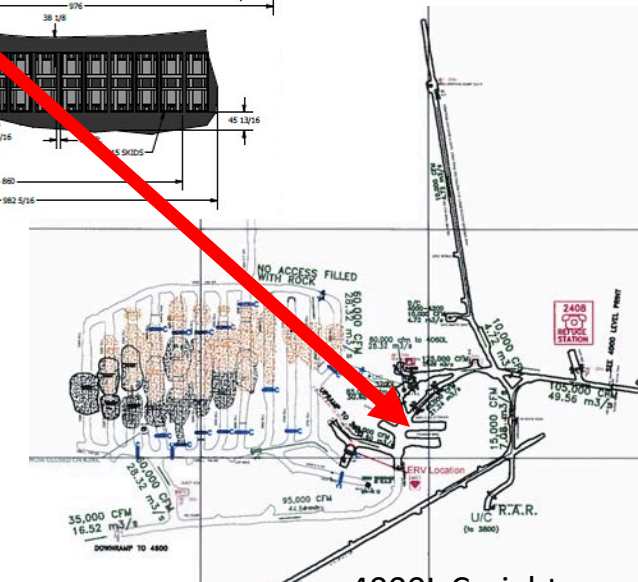
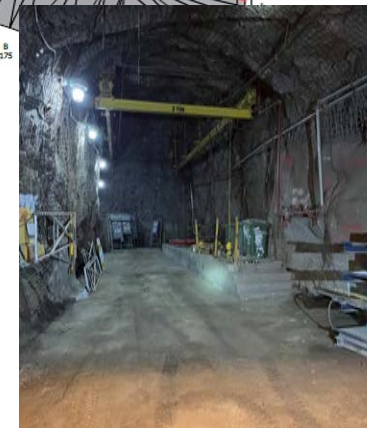
- ARGUS is a project within the GADMC collaboration with the goal to design and procure high pressure argon gas storage and transportation skids, and to store the gas underground at SNOLAB.
- The goal is to store up to 400 tonnes of the low radioactivity argon production from Urania.
- The gas will be stored underground to shield from cosmogenic activation and to be available for next generation experiments (e.g. LEGEND, Argo).
- High pressure gas (500 bar) storage is preferred as storage is compact and low maintenance compared to cryogenic storage.
- Prior to the SNOLAB expansion, the gas skids can be stored at other locations in the mine.
- Location at 4000L level Creighton Mine suitable for ~100 tonnes with minimal development, and can be developed for 400T capacity if required.



Gas skid



Rail car







# Summary / trends

- Direct dark matter and  $0\nu\beta\beta$  decay searches
  - Increasing sensitivity
  - Larger targets / more isotope
  - Must have commensurate reduction in backgrounds
    - Purer materials / underground manufacturing and storage
    - Advances in purification technologies
    - Advances in low background material assay capabilities
    - Larger shielding / increasing space requirements
    - Improved vetoing / tagging of cosmic rays and spallation products
    - When needed – greater depth

# Thanks!

- Questions?

